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LOCAL ACTION WITH INTERNATIONAL COOPERATION TO IMPROVE AND SUSTAIN WATER, SANITATION AND HYGIENE SERVICES

Co-composting of faecal sludge with solid waste to improve FSM practice in Sakhipur municipality

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Sakhipur municipality with 32,000 inhabitants mostly comprise of onsite septic tank and pit toilet of different types. When the pit or septic tank is full, the usual practice is to engage professional sweepers are employed to manually empty them and deposit the wastes in mostly the nearby water bodies. A co-compost plant was designed by the Sakhipur municipality and partners and it's been in operation since 2016 to tackle faecal sludge generated from pit toilets and septic tanks, and solid waste from households exploring sanitation service chain. This study provides a description of an innovative co-composting system which improves current FSM practice in municipality regime. The generated lessons against tackling the operational challenges of sanitation service chain will provide good learnings for replicating similar practice in other municipalities.

Introduction

The majority of people Bangladesh living in urban areas rely on on-site sanitation which generates 'faecal sludge' (FS). Particularly in the unplanned urban settlements of rapidly expanding cities, this FS poses a growing challenge, generating significant public health and environmental risks and impacts. FS is often allowed to accumulate in poorly designed pits, is discharged into storm drains and open water bodies, or is dumped into waterways, wasteland and insanitary landfill sites. In the national sanitation survey, 2003 it was observed that only 58 per cent households had some form of toilets. It substantiates the JMP report in 2000 that shows the open defecation rate was about 19 per cent. However, due to special drives of the Government of Bangladesh and development partners, with active engagement of local government institutions, and the communities, sanitation progress has gained momentum with the focus on building different types of low-cost pit toilets. As a result, the open defecation rates have been gradually reduced to 1 per cent (JMP, 2015). The other side of the fact reveals that 5 m^3 of FS discharge to the open environment equivalents to open defecation of 5000 people per day. Therefore, construction of thousands of pit toilets without thinking of ensuring proper hygienic separation of excreta from human contact and faecal sludge management (FSM) eventually emerged as a second generation sanitation problem for Bangladesh. This paper focuses on capturing lessons from the experience of sustainable services of FSM through innovative technical solutions implemented in Sakhipur municipality of Bangladesh.

FSM services in Bangladesh

FSM is a pressing matter in rural and urban areas of Bangladesh. 61% of the population use improves toilets but the sludge and waste from these toilets are polluting the environment as they not properly treated and disposed of. There are no sewerage systems in the towns and municipalities other than in the capital of Dhaka which covers only about 22 per cent of the total population. In the areas where there is no sewerage network, about 55 per cent of the buildings do not have any septic tanks and these buildings directly discharge the sewage into the open drain, storm drainage and/or the environment resulting pollution of surface water bodies (Jahan and Al-Muyeed, 2015). There is also a lack of treatment facilities for FS and the emptying of on-site sanitation systems mostly dependent upon an unhygienic manual emptying process. Manual emptying and transportation process includes emptying with buckets, and using vans and carts for transport and discharging the faecal waste into the open environment or canals. In some other municipalities, vacutug is used, but numbers and services are inadequate compared to the actual demand.

Sanitation and FSM in Sakhipur

Sakhipur municipality has 32,000 inhabitants. It is rapidly urbanising municipality and is faced with the challenges of poor and insufficient waste management system. There is considerable amount of solid waste that has accumulated over time in and around the city and the city does not have a dedicated sewerage system. Onsite sanitation technologies mostly comprise of septic tank and pit toilet of different types are popular options.

WaterAid Bangladesh conducted a baseline study in 2015 (WaterAid, 2015) and found that the predominant latrines are water sealed pit latrine (82.43%) followed by pit latrine without water sealed (8.21%) and septic tank (5.26%). When the pit or septic tank is full, professional sweepers are employed to manually empty them and deposit the wastes in mostly the nearby water bodies. Accumulated sludge from the onsite sanitation units often overflows, if not emptied and is discharged in nearby open ditches, water bodies and forest. This causes a considerable negative impact on public health and harm to the environment.

6500 metric ton of FS and 3500 metric ton of household SW (WaterAid, 2015) is generated annually in the municipality. About 79% of the FS is discharged from the pits or tanks either by manual emptying or through pipes that directly discharge to the environment. Household waste is disposed in ditches, roadside or into drains mainly as the collection system is inadequate. The municipality has the capacity to collect about 5.0 tons of municipal SW per day and dispose the wastes into landfills (WaterAid, 2015). The Shit Flow diagram before construction of treatment plant in 2015 shows the existing situation [left of Figure 1] when only 21% of FS was safely managed. Following the analysis of the SFD it was decided through a participatory process to involving the municipal authority and other stakeholders to construct a co-composting of FS and organic SW system to address the situation. Vacutug services were also introduced for collection and transportation of FS as an initiative towards modernized transportation and recycling of FS at Sakhipur.

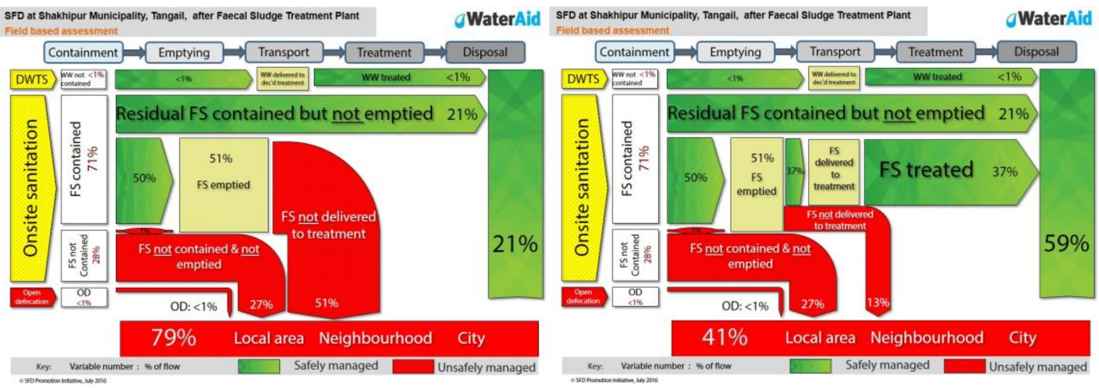

Figure 1. Shit flow diagram of pre and post condition of co-composting in Shakhipur

Technical aspects of FSM interventions

The co-compost plant has also created an opportunity to gain scientific and hands-on knowledge on the technical and operational aspects of co-composting of FS and SW in small towns/municipalities in Bangladesh. On the other hand, good decomposition of organic constituents of FS and SW confirms good quality of soil conditioner or compost. But enduring to safe reuse of developed compost is also a technical challenge. The municipal authority played the central role realizing their need of FSM and leased 0.3 of an acre at the outskirt of the municipal area for the co-compost plant. WaterAid provided technical and financial support and Bangladesh Association of Social Advancement (BASA) worked as the implementation partner. Occupational health & safety measures are taken care in all technical operations following the organisational guideline prepared for local government of GoB and FSM sector actors (OS&H guideline, 2015).

Transportation of faecal sludge

Transportation is a crucial part of a sanitation system to reduce risks of contamination and proper recycling of sludge. Liquid FS is collected from septic tanks and pit toilets by a vacutug owned by the municipality. The capacity of the truck is 1000 litres (L). The FS is collected from within Shakhipur municipality and transported to the co compost plant. The vacutug charges USD 6.5 for each trip irrespective of pit or septic tank within the municipality. Depending on size of the pit and tank, necessary numbers of trips are made. Weekly 16,000-20,000L of FS is collected and discharged on the unplanted drying beds from around sixteen to twenty tanker trips. In the year 2016, more than 800 trips were made to collect faecal waste using Vacutug. It takes around three to five trips to fill one bed as one batch/day. Each batch is kept in the beds for 14 days.

Pre-treatment at drying beds

There are 10 beds, each of $9m^2$ with a loading capacity of maximum 5000L of sludge per bed at a loading depth of about 20cm. They consist of different layers of a gravel-sand filter media of different thickness and gavel sizes (1.25 cm, 2.0 cm and 2.5 cm). The benefits of these beds include no requirement of electrical power and the being built with minimal construction skills and from local materials. The drying process is enhanced by evaporation and solid-liquid separation by gravity percolation of leachate. All ten drying beds are protected by a heavy transparent celluloid sheet covered roof as it is found effective in drying operation (Buro Happold, 2013). The sheet traps heat and aids the drying process. Also during the rainy season, it provides cover from the rain. It is identified that about two weeks is required to separate liquid and solid part of the raw sludge with significant reductions in indicator pathogens. The dried sludge (e,g dry sludge cake) is removed from the bed and left in a maturation bed for one week. The separated liquid part (leachate) of raw FS pre-treated on drying beds further undergone with planted constructed wetland and followed by a polishing pond. The effluent is then discharged into the environment within the Bangladesh effluent discharge standards. *Canna indica*, a perennial is planted out in the constructed wetland to aid further leachate treatment at the constructed wetland.

Collection of household solid waste

Each household pays USD 0.4/month as collection fee. SW is collected and separated for co-composting. The composting plant handles 125 ton of SW a year, and organic components are segregated during the separation process and the inorganic part is recycled and used by different industry that requires it. However, the project has tied with the concept of source separation of SW from households but still it requires manual separation at the plant. This is one of the key challenge of collection of household SW.

Co-composting process

The treatment process follows the batch system where a batch of mixed organic waste (mix of FS and SW) is prepared and aerobically composted separately with intense biological activity from other batches to a final product. The overall performance of the composting process is therefore the combined effect of the activity of individual microorganisms in each batch. Since aerobic metabolism renders more energy for the microorganisms, they grow faster when oxygen is present (Wéry et al. 2008). Heat is produced in aerobic decomposition of waste, which is a highly exothermic process. Therefore, mixing ratio is an important factor for co-composting. In each batch process, the organic SW, dried FS and saw dust are mixed with a volume ratio of 3:1:1 to get efficient aerobic bacterial activity. The saw dust is added as amendment (Zorpas and Loizidou 2008) to maintain optimum porosity of the compost matrix to near 70-80% (v/v) and to keep moisture content of the mixed content to about 60% by weight. It also increases the carbon to nitrogen (C: N) ratio of the matrix. There are number of sawmills (woodcutting industry) at the nearby locality where sawdust is readily available at cheaper rate. If the C: N ratio is high beyond 30, aerobic decomposition slows down. If the C: N ratio is low (less than 5), organic decomposition rate becomes slow due to inhibition of bacterial activity resulting possible anaerobic mining or inhibition inside the compost matrix (Onwosi et al. 2017).

SW has higher C:N ratio (15:1- 25:1) and FS has lower C: N ratio (about 3:1-5:1). By mixing the organic contents (FS and SW) with saw dust (C:N ratio>60) improve the proportion of the initial compost matrix is at about 15:1. The mixture is then composted aerobically for eight weeks. Turning, watering, temperature measurement, weighing, sampling and laboratory analysis are carried out during a composting cycle.

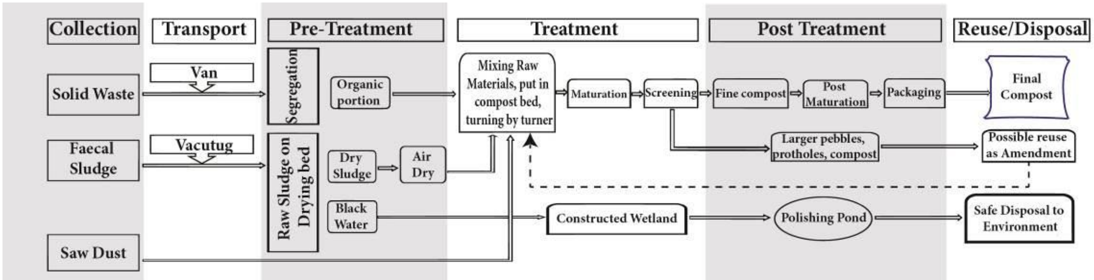

Figure 2. Faecal sludge service chain in Shakhipur municipality

Turning of compost mass during decomposition process has many important functions, e.g. supplying oxygen, redistributing the waste products generated by degradation reaction, redistributing some anaerobic zone, releasing excess water content, etc. A customised locally made mechanical turner is used to confirm uniform mixing during starting of the operation and then turning of the mixture regularly at three days' interval to release inhibition effect during decomposition. The temperature data is captured using continuous data logger (HOBO-U12) and thermophilic composting is identified during eight weeks of decomposition period (Figure 3). During the eight weeks of composting, moisture content reduces to about 25% from 60%. It further reduces to less than 15% while maturation process (under natural air) takes place for one week.

Maturity of compost

The maturity of compost is important for application purposes; fresh and matured composts are distinguished prior to marketing to apply the compost as soil conditioner. Many researchers (Bernai et al. 1998; Canet & Pomares 1995) suggest that, the degree of compost maturity is calculated by the maximum self-heating temperature measured in different phase of composting. Figure 3 depicts the maturity index of compost mass after end of decomposition at 8 weeks by self-heating approach. It is evident that the compost mass reached at the maturity phase III where most of the substrates have been decomposed. Few more days of natural curing would be enough to ensure phase IV level of maturation. Compost material has been put further 1 week of natural air curing to ensure end of substrate decomposition.

Hygienic implication of compost

Research (Jenkins 2005) has shown that compost achieving the "temperature/time" regime required for proper operation of large, permitted composting facilities is effective in pathogen destruction although subsequent recontamination of the compost and re-growth of microorganisms can be a problem. It is commonly believed that reaching temperatures of 55°C for 3 days is sufficient to essentially eliminate bacterial pathogens for SW composting. However, for co-composting there is lack of appropriate research on this issue. Recent work (IWA 2014) suggests also that the control of bacterial pathogens in composting is more complex and not simply the result of thermal treatment. Salmonella, E. coli, and other bacteria survived high temperatures for a significant time, but whether the high temperature resistant strains are pathogenic is unknown. Moisture level, for example, is also important in the survival of E. coli through the composting process. It has been suggested (IWA 2014) that microbial competition is also important in the destruction of pathogenic organisms in compost. If so, if finished composts with low levels of competing microorganisms become inoculated with pathogens, there would be an increased potential for high pathogen levels due to re-growth in the absence of competition. The compost after 1 week of natural curing is then kept in a post maturation chamber where it undergoes hot air treatment for 48-72 hours to ensure hygienic use of the product before packaging for agricultural use (Wei and Liu 2005). The moisture content settles in between 12 to15% after hot air treatment during post maturation.

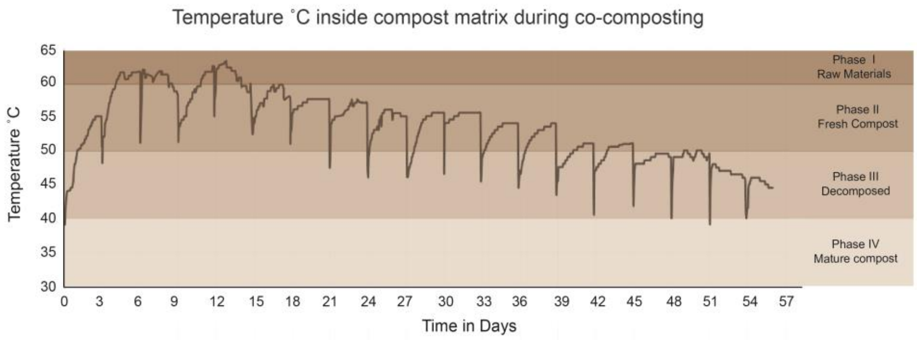

Figure 3. Temperature ˚C inside compost matrix during co-composting

Reuse of compost product

The laboratory tests report at the Soil Resource Development Institute of Bangladesh shows the end product is reusable as soil conditioner and is free from hazard of heavy metals (Table 1). About 24 ton/year of compost is produced by treating 1200 ton FS and 125 ton of SW. The department of agricultural extension of the Sakhipur municipality has been providing further technical guidance for proper reusing and distributing the compost among the local farmers for USD 0.2 per kilogram. The farmers use the compost as soil conditioner and their feedback is encouraging. The compost is in high demand in and around the town.

Environmental improvement

Shit flow diagrams (SFD) were developed to identify the pre and post condition of the municipality. The pre-condition of the municipality was quiet alarming (21% generated FS safely managed) during 2015. But the introduction of the co-compost plant has increased significantly to 59% safely managed FS by end of end of two years of operation (right side of Figure 1) as desludging period of septic tank and pit was considered for 2 years. The treatment plant is now treating about 18% of the generated sludge of the municipality per year.

Table 1. Chemical analysis of the sample co-compost

Parameter	Colour	Physical conditions	Odour	pH	Moisture	Organic Carbon	Total Nitrogen (N)	C:N
Bangladesh Standard	Dark grey to black	Non-granular form	Absence of foul odour	6.0-8.5	15-20%	10-25%	0.5-4.0%	20:1
Test Result	Dark Grey	Non-granular form	Absence of foul odour	7.2	17 .9%	14.5%	1.75%	8:3:1

Parameter	Sulphur (K)	Phosphorous (P)	Chromium (Cr)	Cadmium (Cd)	Lead (Pb)	Nickel (Ni)	Zinc (Zn)	Inert material	Copper (Cu)
Bangladesh Standard	0.1-0.5%	0.5-3.0%	50 ppm	5 ppm	30 ppm	30 ppm	0.1% (max)	0.5-4.0%	0.05% (max)
Test Result	0.1%	0.78%	14.14 ppm	1.05 ppm	15.50 ppm	11.82 ppm	0.06 %	1.75%	0.0001 %

Operation and maintenance aspects

The municipal authority set a tariff system through a participatory approach for collecting sludge through vacutug and door to door SW collection. FS collection and transportation fee is about 6.5 USD per trip (each trip collects 1000L of sludge) within the Municipality area; clients outside the Municipality pay for the extra fuel cost. It is estimated that annually around USD 7000 is collected in fees from both these services.

Additionally, USD 6000 per year has been collected from selling the compost. Operation of the co-composting plant is labour intensive. SW sorting is the costliest activity contributing to approx. 30% of the total operation and maintenance costs. It is calculated that first year O&M cost is 20621 USD against its income of 13051 USD. The first year of O&M of co-compost plant has much learning particularly about having a suitable business approach for its sustainability.

Lessons learned

The co-compost plant has experienced few lessons learnt during operation:

- Technical knowhow on co-composting is challenging where the microbiological activity that renders co-composting process depends upon a number of controlling factors like mixing ratio, moisture content, aerobes bacteria and uniform turning.
- A solar powered hot air blower (post maturation chamber) is introduced after eight weeks of composting for pathogen reduction. This is an engineering way to get a safe and stable compost product as moisture content reduces to less than 16% and most of the common pathogens should die or become inactive inside the chamber. And the innovation of such technology also leads to keeping a safe zone against pathogenic activities as per suggestion of the World Health Organisation's handbook (Jenkins 2005). However, research is further required to consider the newly adapted sanitation safety plan by WHO (WHO, 2006).
- Due to seasonal variations, more liquid sludge is collected in the wet season. The highest demand on collection and transport services occurs during the rainy season, as heavy rainfalls result in overflowing and flooding of onsite systems. Consequently, the volume of dry sludge is reduced which has an effect in compost operation. To keep the dry sludge amount within suitable range, beds are filled upto 5000L per bed often during rainy season.
- An important issue is whether subsidy is needed for such treatment system by municipal led approach. The lessons learnt from a year of O&M prompts to get a sustainable context specific business approach through a full life cycle analysis.

Conclusion

The co-compost plant exemplifies how to effectively deal with SW and FS induced environmental pollution with context specific innovation of FSM technologies and sustainable services. The innovative solution and municipal led approach already gets the attention of the government and sector actors to tackle the pressing second generation sanitation problems in Bangladesh. Therefore, a sustainable business approach to operate such treatment plant needs to associate full life cycle analysis. The recent political will of the government to develop institutional and regulatory framework of FSM is a much inspiring one, which could help turn such technological innovations into widespread practice. Further extended research is required to validate such engineering conceptual design. The journey has just begun.

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